Teacher Resource

National Park Service
U.S. Department of the Interior

Fossil Butte National Monument
Kemmerer, Wyoming

Teacher's Guide and Answer Key for Leafy Thermometers and Rain Gauges

Leaf Margin and Area Analysis

The use of leaves from woody dicotyledonous trees and shrubs as climate indicators dates to the work of Sinnott and Bailey in 1915. Over the years it has been refined and tested by many other researchers in locations worldwide. With few exceptions, the basic assumption that correlation of mean annual temperature with leaf than rather than are influenced primarily by climate. A recent scientific paper by Little, Kembel

Contact Information—e-mail: fobu_interpretation@nps.gov, phone: 307 877-4455, or mailing address: Fossil Butte National Monument, PO Box 592, Kemmerer, WY 83101. The activity and supporting materials are available at <www.nps.gov/fobu> under the quick-link tab *For Teachers*. All materials may be reproduced for educational use. Comments and suggestions are encouraged, and should be forwarded to the education specialist using contact information provided above.

Answer Keys for Leaf Sets

	Demo	Leaf Set 1		Leaf Set 2	
Leaf ID Number	UMNH PB154	NAMLA 1	FOBU 6544	FOBU 13328	FOBU 9978
Step 1	marginal	Peltate	marginal	marginal	marginal
Step 2	unlobed		unlobed	lobed	unlobed
Step 3	pinnate		pinnate	pinnate	pinnate
Step 4	untoothed	untoothed	untoothed	toothed	untoothed
Step 5	no agrophics		no agrophics		no agrophics
Step 6	brochidodromous		eucamptodromous or brochidodromous		brochidodromous
Step 7	obovate		elliptic		elliptic
Bin number	26	12	30 or 24	13	24
Leaf length	49	188	78	23	196
Leaf width	15	167	14	7	83
Leaf area	551.25	23547	819	120.75	12201
Size Class	microphyll	macrophyll	microphyll	nanophyll	mesophyll

	Demo	Leaf Set 3		Leaf Set 4	
Leaf ID Number	UMNH PB154	FOBU 10688	Stanley 1	Robbie Ray 1	FOBU 11582
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	lobed	unlobed	lobed	unlobed
Step 3	pinnate	palmate or pinnate	pinnate	palmate	pinnate
Step 4	untoothed	untoothed	untoothed	toothed	untoothed
Step 5	no agrophics		no agrophics		no agrophics
Step 6	brochidodromous		eucamptodromous or brochidodromous		brochidodromous
Step 7	obovate		blank or elliptic		elliptic
Bin number	26	14 or 13	30 or 24	14	24
Leaf length	49	197	36	97	53
Leaf width	15	134	32	102	18
Leaf area	551.25	19798.5	864	7420.5	715.5
Size Class	microphyll	macrophyll	microphyll	mesophyll	microphyll

	Demo	Leaf Set 5		Leaf Set 6	
Leaf ID Number	UMNH PB154	UMNH PB225	FOBU 11590	FOBU11733	UMNH PB141
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	pinnate	pinnate	pinnate
Step 4	untoothed	toothed	untoothed	toothed	untoothed
Step 5	no agrophics	no agrophics or agrophics	no agrophics	no agrophics	no agrophics
Step 6	brochidodromous	craspedodromous	eucamtodromous or brochidodromous	semicraspedodromous	eucamptodromous or brochidodromous
Step 7	obovate	elliptic or blank	blank or elliptic		blank or elliptic
Bin number	26	19 or17	30 or 24	16	30 or 24
Leaf length	49	65	95	126	68
Leaf width	15	29	47	42	20
Leaf area	551.25	1413.75	3348.75	3969	1020
Size Class	microphyll	microphyll	notophyll	notophyll	microphyll

	Demo	Leaf Set 7		Leaf Set 8	
Leaf ID Number	UMNH PB154	FOBU 10685	FOBU 10730	FOBU10681	FOBU 9838
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	pinnate	pinnate	pinnate
Step 4	untoothed	toothed	untoothed	toothed	untoothed
Step 5	no agrophics	no agrophics	no agrophics	no agrophics	no agrophics
Step 6	brochidodromous	semicraspedodromous	brochidodromous	semicraspedodromous	eucamptodromous or brochidodromous
Step 7	obovate		elliptic		blank or elliptic
Bin number	26	16	24	16	30 or 24
Leaf length	49	46	87	85	95
Leaf width	15	16	32	35	25
Leaf area	551.25	552	2088	2231.25	1781.25
Size Class	microphyll	microphyll	notophyll	notophyll	microphyll

	Demo	Leaf Set 9		Leaf Set 10	
Leaf ID Number	UMNH PB154	FOBU 11467	FOBU 11645	FOBU13064	FOBU 13056
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	pinnate	pinnate	pinnate
Step 4	untoothed	toothed or untoothed	untoothed	toothed	untoothed
Step 5	no agrophics	no agrophics	no agrophics	no agrophics	agrophics
Step 6	brochidodromous	semicraspedodromous or eucamptodromous	eucamptodromous or brochidodromous	semicraspedodromous	eucamptodromous or brochidodromous
Step 7	obovate		blank or elliptic		
Bin number	26	16 or 30	30 or 24	16	29 or 22
Leaf length	49	87	74	122	150
Leaf width	15	34	12	32	64
Leaf area	551.25	2218.5	666	2928	7200
Size Class	microphyll	notophyll	microphyll	notophyll	mesophyll

	Demo	Leaf Set 11		Leaf Set 12	
Leaf ID Number	UMNH PB154	UMNH PB196	UMNH PB90	UMNH PB112	FOBU 13317
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	pinnate	pinnate	pinnate
Step 4	untoothed	toothed	untoothed	toothed	untoothed
Step 5	no agrophics	no agrophics	agrophics or no agrophics	no agrophics	no agrophics
Step 6	brochidodromous	semicraspedodromous	brochidodromous	craspedodromous or semicraspedodromous	eucamptodromous
Step 7	obovate		blank or elliptic	elliptic or blank	
Bin number	26	16	22 or 24	19 or 16	30
Leaf length	49	174	77	110	95
Leaf width	15	64	67	45	28
Leaf area	551.25	8352	3869.25	3712.5	1995
Size Class	microphyll	mesophyll	notophyll	notophyll	microphyll

	Demo	Leaf Set 13		Leaf Set 14	
Leaf ID Number	UMNH PB154	FOBU 13035	FOBU 10746	FOBU 11794	FOBU 13013
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	pinnate	pinnate	pinnate or palmate
Step 4	untoothed	toothed	untoothed	toothed	toothed
Step 5	no agrophics	no agrophics	no agrophics	no agrophics	agrophics
Step 6	brochidodromous	craspedodromous	craspedodromous	craspedodromous	semicraspedodromous or eucamptodromous
Step 7	obovate	ovate		ovate	
Bin number	26	18	28	18	15, 31, 29 or 39
Leaf length	49	123	68	81	130
Leaf width	15	45	27	15	54
Leaf area	551.25	4151.25	1377	911.25	5265
Size Class	microphyll	notophyll	microphyll	microphyll	mesophyll

	Demo	Leaf Set 15		Leaf Set 16	
Leaf ID Number	UMNH PB154	UMNH PB35	FOBU 9213	UMNH PB152	FOBU 13058
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed or lobed
Step 3	pinnate	pinnate	palmate or pinnate	pinnate	palmate
Step 4	untoothed	toothed	toothed	toothed	toothed
Step 5	no agrophics	no agrophics	agrophics	no agrophics	agrophics
Step 6	brochidodromous	craspedodromous	semicraspedodromous or craspedodromous	craspedodromous or semicraspedodromous	craspedodromous
Step 7	obovate	ovate		elliptic or blank	
Bin number	26	18	31, 33, 15 or 17	19 or 16	33
Leaf length	49	180	90-97	58	142
Leaf width	15	47	120	32	117
Leaf area	551.25	6345	10800-11640	1392	12460.5
Size Class	microphyll	mesophyll	mesophyll	microphyll	mesophyll

	Demo	Leaf Set 17		Leaf Set 18	
Leaf ID Number	UMNH PB154	UMNH PB169	Stanley 2	FOBU 13014	FOBU 13287
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate	palmate	pinnate	palmate
Step 4	untoothed	toothed	toothed	toothed	untoothed
Step 5	no agrophics	no agrophics	agrophics	no agrophics	agrophics
Step 6	brochidodromous	semicraspedodromous or craspedodromous	craspedodromous	craspedodromous	craspedodromous or brochidodromous
Step 7	obovate	blank or elliptic		ovate, oblong or elliptic	
Bin number	26	16 or 19	33	18, 20 or 19	37 or 35
Leaf length	49	50	66	47	97
Leaf width	15	23	46	13	87
Leaf area	551.25	862.5	2277	458.25	6329.25
Size Class	microphyll	microphyll	notophyll	microphyll	mesophyll

	Demo	Leaf Set 19		Leaf Set 20	
Leaf ID Number	UMNH PB154	FOBU 10684	FOBU 11743	FOBU 10123	FOBU 13073
Step 1	marginal	marginal	marginal	marginal	marginal
Step 2	unlobed	unlobed	unlobed	unlobed	unlobed
Step 3	pinnate	pinnate or palmate	palmate or pinnate	pinnate or palmate	pinnate or palmate
Step 4	untoothed	untoothed	untoothed	untoothed	untoothed
Step 5	no agrophics	agrophics	no agrophics	agrophics	no agrophics
Step 6	brochidodromous	craspedodromous or brochidodromous	brochidodromous	craspedodromous	brochidodromous
Step 7	obovate		elliptic		elliptic or blank
Bin number	26	27, 37, 22 or 35	24	27 or 37	24 or 36
Leaf length	49	43	80	88	72
Leaf width	15	45	27	45	17
Leaf area	551.25	1451.25	1620	2970	918
Size Class	microphyll	microphyll	microphyll	notophyll	microphyll

Bin number	A leaves	B woody dicots	C morphotypes	D untoothed	E mesophyll	F macrophyll	G megaphyll
12	1	0	0	0	0	0	0
13	1-2	1-2	1-2	0-1	0	0-1	0
14	1-3	1-3	1-3	0-1	1-2	0-1	0
15	0-2	0-2	0-2	0	0-1	0	0
16	5-9	5-9	4-8	0	1	0	0
17	0-2	0-2	0-2	0	0-1	0	0
18	3	3	3	0	1	0	0
19	0-4	0-4	0-4	0	0	0	0
20	0-1	0-1	0-1	0	0	0	0
21	0	0	0	0	0	0	0
22	1-6	1-6	1-6	1-5	1	0	0
23	0	0	0	0	0	0	0
24	8-11	8-11	8-11	8-11	1	0	0
25	0	0	0	0	0	0	0
26	1	1	1	1	0	0	0
27	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0
29	0-3	0-3	0-3	0-3	0	0	0
30	1-3	1-3	1-3	1-3	0	0	0
31	1-2	1-2	1-2	0	1-2	0	0
32	0	0	0	0	0	0	0
33	1-3	1-3	1-3	0	0-2	0	0
34	0	0	0	0	0	0	0
35	0-5	0-5	0-5	0-5	0-1	0	0
36	0-1	0-1	0-1	0-1	0	0	0
37	0-1	0-1	0-1	0-1	0	0	0
38	0	0	0	0	0	0	0
39	0-1	0-1	0-1	0-1	0	0	0
40	0	0	0	0	0	0	0
Total	41	40	39	20-21	9	1	0

Table 1 *(Climate Analysis Worksheet)*

Part B. Leaf Margin Analysis and Mean Annual Temperature

1. Use the data from **Table 1** to determine the proportion of untoothed morphotypes (P_U) in the fossil leaf data set. Use the equation $\mathbf{P_U = \frac{Column\ D_{TOTAL}}{Column\ C_{TOTAL}}}$ to calculate the proportion. Show your work to 4 decimal places.

   P_u = 20 untoothed / 39 morphotypes = 0.5128 OR **P_u = 21 untoothed / 39 morphotypes = 0.5385**

2. Calculate mean annual temperature (MAT) to 2 decimal places using the equation **MAT (°C) = (28.99 x P_U) + 1.32**. Show your work to 2 decimal places.

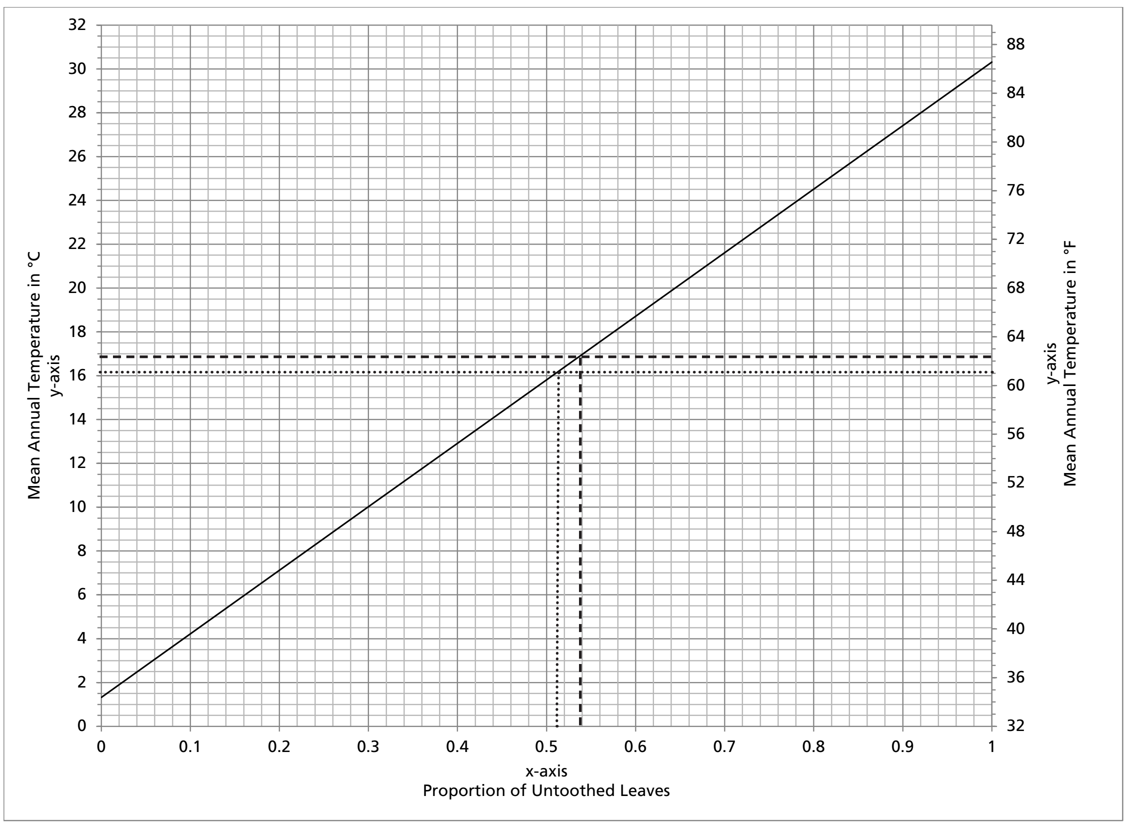
   MAT (°C) = (28.99 x 0.5128) + 1.32
   = 14.87 + 1.32
   = 16.19°C

   OR

   MAT (°C) = (28.99 x 0.5385) + 1.32
   = 15.61 + 1.32
   = 16.93°C

3. The diagonal line on graph below represents the relationship between the proportion of untoothed leaves (P_U) and mean annual temperature (MAT). It has a **negative slope** / **positive slope** (circle one) meaning the more untoothed leaves a place has the **cooler** / **warmer** (circle one) the average temperature is. Use the graph below to determine mean annual temperature (MAT) in °C and °F.

   Step 1. Find the proportion of untoothed leaves (P_U) on the horizontal x-axis of the graph.
   Step 2. Draw a vertical line using a ruler from P_U on the x-axis until it intersects the diagonal line.
   Step 3. From the point of intersection with the diagonal line, draw a horizontal line using a ruler that intersects both vertical y-axes of the graph.



4. Read the mean annual temperature in °C from intersection of the horizontal line with the y-axis to the left. Record your answer below. Does the graphical solution agree with the algebraic solution in question 2? If they do not agree within 0.5°C you need to check both solutions.

   --- 16.2°C, acceptable answers 15.7 to 16.7°C
   OR
   – – 16.9°C, acceptable answers 16.4 to 17.4°C

5. Read the mean annual temperature in °F from intersection of the horizontal line with the y-axis to the right. Record your answer below.

   --- 61.1°F, acceptable answers 60.6 to 61.6°F
   OR
   – – 62.3°F, acceptable answers 62.0 to 63.0°F

Part C. Leaf Area Analysis and Mean Annual Precipitation

1. Use the data from **Table 1** to determine the proportion of large-leaved morphotypes (P_L) in the fossil leaf data set. Use the equation $\mathbf{P_L = \frac{(Column\ E_{TOTAL} + Column\ F_{TOTAL} + Column\ G_{TOTAL})}{Column\ C_{TOTAL}}}$ to calculate P_L. Show your work to 4 decimal places.

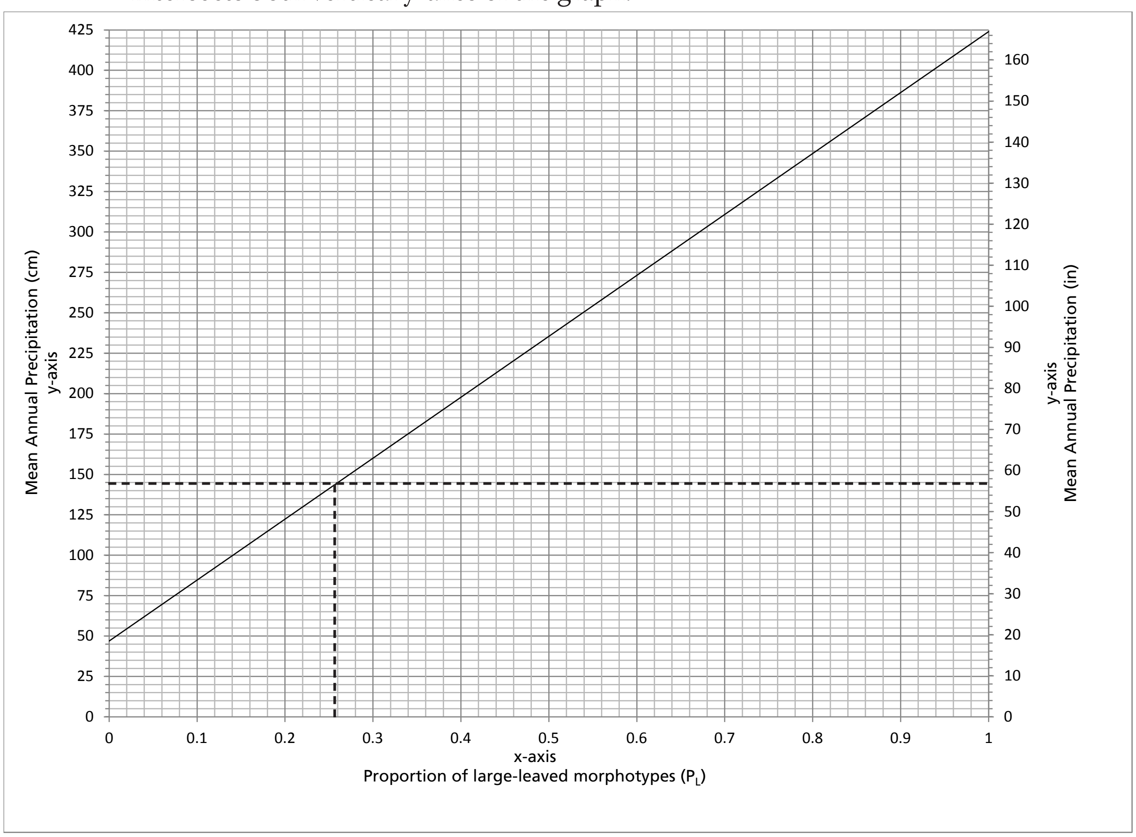
P_L = (9+1+0) large-leaved morphotypes / 39 morphotypes
= 10 large-leaved morphotypes / 39 morphotypes
= 0.2564

2. Calculate mean annual precipitation (MAP) using the equation **MAP (cm) = (377 x P_L) + 47**. Show your work to 2 decimal places.

MAP (cm)= (377 x 0.2564) + 47
= 96.66 + 47
= 143.66 cm

3. The diagonal line on the graph below represents the relationship between the proportion of large-leaved morphotypes (P_L) and mean annual precipitation (MAP). It has a **negative slope** / **positive slope** (circle one) meaning the more large leaves a place has the **less precipitation** / **more precipitation** (circle one) it receives annually. Use the graph to estimate mean annual precipitation (MAP) in centimeters and inches.

Step 1. Locate the proportion of large-leaved morphotypes (P_L) on the horizontal x-axis of the graph.
Step 2. Draw a vertical line using a ruler from P_L on the x-axis until it intersects the diagonal line.
Step 3. From the point of intersection with the diagonal line, draw a horizontal line using a ruler that intersects both vertical y-axes of the graph.



4. Read the mean annual precipitation in centimeters (cm) from intersection of the horizontal line with the y-axis to the left. Record your answer below. Does the graphical solution agree with the algebraic solution in question 2? If they do not agree within 5 centimeters you need to check both solutions.

144 cm, acceptable answers 138.7 to 148.7 cm

5. Read the mean annual precipitation in inches (in) from intersection of the horizontal line with the y-axis to the right. Record your answer below.

56.5 in, acceptable answers 54.7 to 58.7 in

Part D. Modern Climatology Data

1. Convert the mean annual temperature (MAT) in °C from Part B question 2 to °F using the formula: $°F = \frac{(9 \times °C)}{5} + 32$. Show your work. Record answer in **Table 2**. Round your answer to 1 decimal place.

MAT (°F) = ((9 x 16.19) / 5) + 32
= (145.71 / 5) + 32
= 29.14 + 32
= 61.1°F

OR

MAT (°F) = ((9 x 16.93) / 5) + 32
= (152.37 / 5) + 32
= 30.47 + 32
= 62.5°F

2. Convert the mean annual precipitation (MAP) in centimeters from Part C question 2 to inches using the formula: $in = \frac{cm}{2.54}$. Show your work. Record answer in **Table 2**. Round your answer to 1 decimal place.

MAP (in) = 143.67 / 2.54
= 56.7 in

3. Go to the Wyoming Climate Summaries web site at <www.wrcc.dri.edu/summary/climsmwy.html> and click on the links in the left margin for Fossil Butte, Kemmerer and Sage one station at a time. Record the *Annual Average Max. Temperature* (equivalent to T_{MAX} in **Table 2**), the *Annual Average Min. Temperature* (equivalent to T_{MIN} in **Table 2**) and *Annual Average Total Precipitation* (equivalent to MAP in **Table 2**) for each station.

4. To estimate mean annual temperature (MAT) for Fossil Butte, Kemmerer and Sage average T_{MAX} and T_{MIN}. Use the equation: $MAT = \frac{(T_{MAX} + T_{MIN})}{2}$. Show your work. Record answers in **Table 2**.

Fossil Butte:
MAT (°F) = (54.6 + 23.6) / 2
= 78.2 / 2
= 39.1°F

Kemmerer:
MAT (°F) = (53.9 + 23.7) / 2
= 77.6 / 2
= 38.8°F

Sage:
MAT (°F) = (55.5 + 21.0) / 2
= 76.5 / 2
= 38.25°F

	Fossil Leaves	Fossil Butte	Kemmerer	Sage
T_{MAX}	Blank	**54.6°F**	**53.9°F**	**55.5°F**
T_{MIN}	Blank	**23.6°F**	**23.7°F**	**21.0°F**
MAT	**61.1°F OR 62.5°F**	**39.1°F**	**38.8°F**	**38.25°F**
MAP	**56.7 in**	**10.78 in**	**9.39 in**	**9.69 in**

Table 2

6. What general statement can be made about climate change over the last 52 million years in southwestern Wyoming based on the results in **Table 2**?

Southwestern Wyoming's climate has become much cooler and drier over the last 52 million years.

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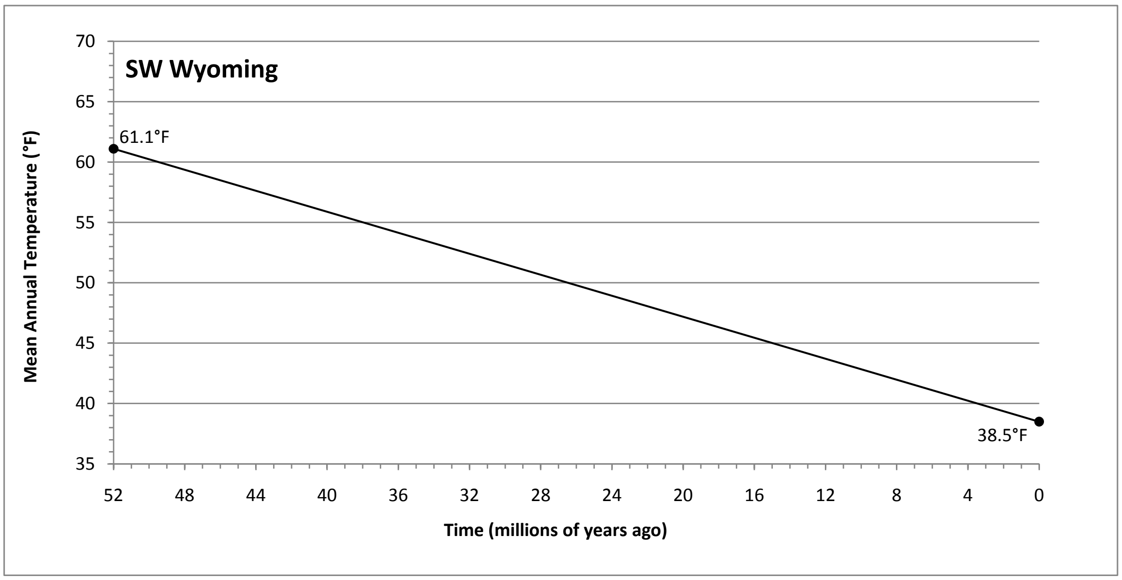
Climate Change Worksheet

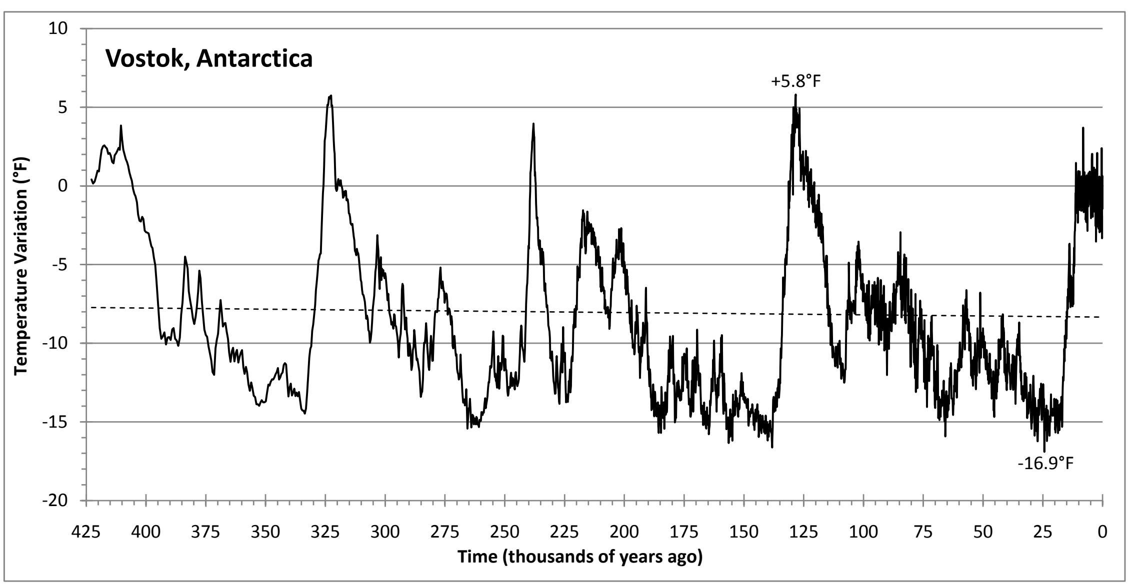
1. **Graphs** 1 and 2 show how temperature has changed over geologic time. Read the captions, compare the graphs and list three differences. [Bonus: List one similarity.]

1) Graph 1 uses the actual temperature and Graph 2 uses temperature variation. 2) Graph 1 measures time in millions of years and Graph 2 measures it in thousands of years. 3) Graph 1 has only 2 data points, while Graph 2 has many (actually 3311). 4) Graph 1 is a straight line, while Graph 2 is a jagged line with many peaks and valleys. 5) Graph 1 is from a location in the northern hemisphere and Graph 2 is located in the southern hemisphere.

<u>Bonus</u>: 1) The maximum temperature change in both graphs are nearly the same, 22.6°F in Graph 1 and 22.7°F in Graph 2 (This pure coincidence). 2) Both graphs indicate temperatures have been cooling over the respective time frames, pronounced in Graph 1 and minimal in Graph 2. 3) Both graphs represent a single point on the Earth's surface.



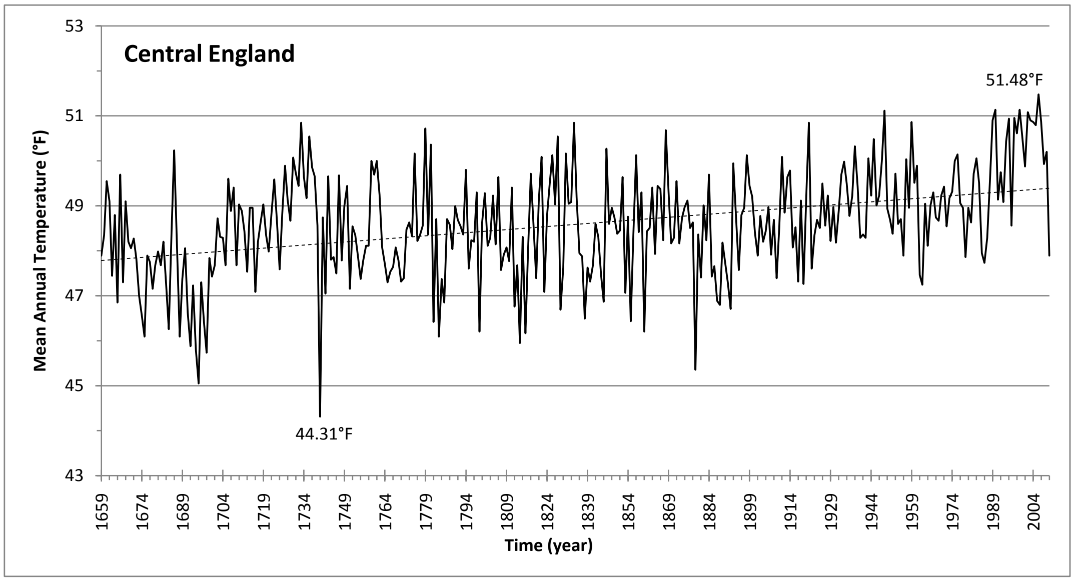
Graph 1—The graph shows the temperature change over the last 52 million years in southwestern Wyoming based on the analysis of fossil leaves (P. Kester and A. Aase, pers. com., 2011) and modern observational data. The mean annual temperature 52 million years ago was 61.1°F and today it is 38.5°F, a difference of 22.6°F.



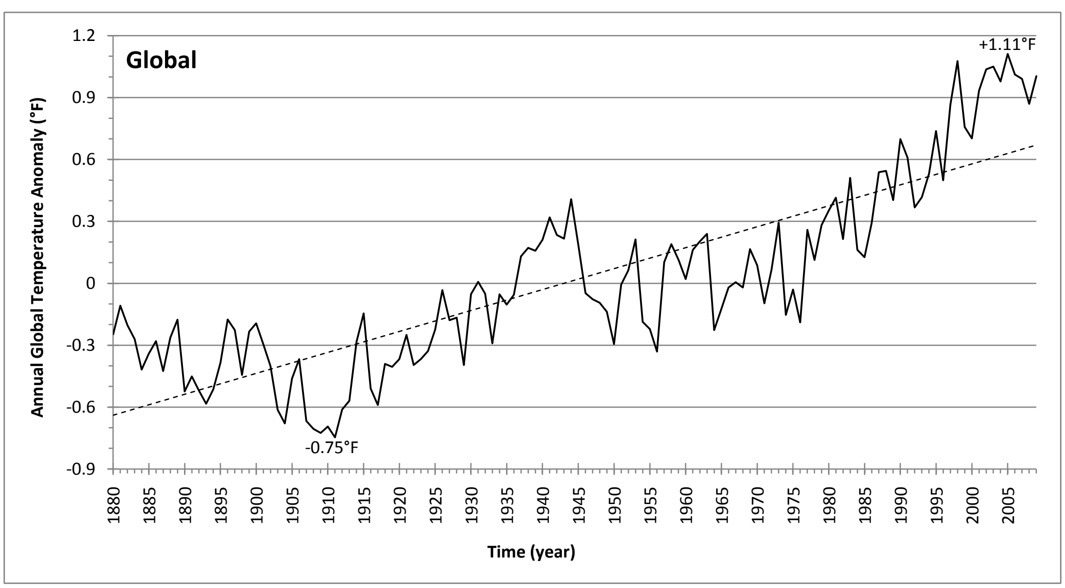
Graph 2—The graph (based on Petit, J.R. et al, 1999) shows the variation in temperature over the last 425,000 years at Vostok, Antarctica as determined from ice cores. The five tallest peaks represent short-lived warm periods that interrupted major glaciations. During the height of a warm period about 125,000 years ago, temperatures were 5.8°F warmer than today. At the last glacial extreme about 25,000 years ago they were 16.9°F cooler, a difference of 22.7°F.

2. **Graphs 3** and 4 show how temperature has changed as advanced human civilization developed. Read the captions, compare the graphs and list three differences.

1) Graph 3 uses the actual temperature and Graph 4 uses temperature anomalies which are variations from a long-term average. 2) Graph 3 covers a longer period in years than Graph 4. 3) Graph 3 has more data points than Graph 4 (352 vs 130). 4) Graph 3 represents what is happening at a single location, while graph 4 is an average from a network of global locations. 5) The maximum temperature change in Graph 3 is much greater than in Graph 4 (7.17°F vs 1.86°F).



Graph 3—The graph (based on Parker, D.E. et al, 1992) shows mean annual temperature for Central England from 1659 to 2010. It is the longest continuous temperature record in existence. The lowest mean annual temperature over this period was 44.31°F in 1740 and the highest was 51.48°F in 2006, a difference of 7.17°F.



Graph 4—The graph (based on data from the National Climate Data Center) shows the annual global temperature anomaly for 1880-2009. A temperature anomaly is the difference between an observed temperature and a long-term average temperature. The largest negative anomaly over this period was -0.75°F in 1911 and the largest positive anomaly was 1.11°F in 2005, a difference of 1.86°F.

3. Why does **Graph 1** look so different from the other three? [Hint: Give a pointed answer.]

Graph 1 is a straight line, while Graphs 2-4 are jagged lines with many peaks and valleys. This is because Graph 1 was drawn using just 2 data points and Graphs 2-4 used many data points.

4. Why is a global average, as opposed to data from a single location, a more meaningful measure of climate change?

A global average has data from a network of stations across the earth's surface. This reduces the effects of unusual weather at one or more individual locations resulting in a more reliable measure of climate change.

5. The methods used to produce the graphs are different, but what do they all show? [Hint: Look to axes]

They all reveal how temperature has varied over time.

6. The dashed line in the last three graphs are linear trendlines. Trendlines smooth the peaks and valleys using an averaging technique to reveal the direction and magnitude of change over a period of time.

Step 1. Calculate the change in temperature, $\Delta T(°F)$, for Vostok, Antarctica, Central England and Global using data in the table below and the equation: $\Delta \mathbf{T(°F)} = \mathbf{t_{min}} - \mathbf{t_{max}}$. Show your work.

	SW Wyoming		Vostok, Antarctica		Central England		Global	
	t_{min}	t_{max}	t_{min}	t_{max}	t_{min}	t_{max}	t_{min}	t_{max}
T (°F)	38.5	61.1	-8.3358	-7.7408	49.44	47.825	0.7688	-0.547

Example (SW Wyoming):
from table, t_{min} = 38.5°F
from table, t_{max} = 61.1°F
$\Delta T(°F)$ = 38.5°F - 61.1°F
= -22.6°F

Vostok, Antarctica:
ΔT(°F) = -8.3358 - (-7.7408)
= -0.595°F

Central England:
ΔT(°F) = 49.44 - 47.825
= 1.615°F

Global:
ΔT(°F) = 0.7688 - (-0.547)
= 1.3158°F

Record your anwers here.

	SW Wyoming	Vostok, Antarctica	Central England	Global
$\Delta T(°F)$	-22.6	**-0.595**	**1.615**	**1.3158**

Step 2. Calculate the rate of temperature change per century, $\Delta T/t$(°F per century), for Vostok, Anarctica, Central England and Global using data from Step 1, the table below, and the following equation. Show your work and round answer to 5 decimal places.

$$\Delta T/t(°F/100\ yrs) = \frac{\Delta T\ (°F)}{\Delta t\ (yrs)} \times 100$$

	SW Wyoming	Vostok, Antarctica	Central England	Global
Δt(yrs)	52,000,000	425,000	352	130

Example (SW Wyoming):
from Step 1, ΔT (°F) = -22.6°F
from table, Δt (yrs) = 52,000,000 yrs

$$\Delta T/t\ (°F/100\ yrs) = \frac{-22.6°F}{52{,}000{,}000\ yrs} \times 100$$
$$= -0.00005°F/100yrs$$

Vostok, Antarctica:
$\Delta T/t$(°F per century) = (-0.595 / 425,0000) x 100
= -0.00014°F per century

Central England:
$\Delta T/t$(°F per century) = (1.615 / 352) x 100
= 0.45881°F per century

Global:
$\Delta T/t$(°F per century) = (1.3148 / 180) x 100
= 1.01215°F per century

Record your answers here.

	SW Wyoming	Vostok, Antarctica	Central England	Global
$\Delta T/t$(°F/100 yrs)	-0.00005	**-0.00014**	**0.45881**	**1.01215**

7. Compare the rates of temperature change per century. The short-term records (Central England and Global) suggest Earth's surface temperature is ___**warming**___ (**cooling**, or **warming**) significantly, while the long-term records (SW Wyoming and Vostok, Antarctica) suggest it has ___**cooling**___ (**cooled**, or **warmed**) albeit very slowly.

8. In your opinion, why does, or doesn't the evidence presented support a conclusion that modern climate change is being influenced by humans (anthropogenic climate change)?

9. Use the internet to investigate three factors (one anthropogenic and two natural) that influence Earth's climate. On separate index cards list each factor, what its influence is and how that varies over time. Be prepared to discuss the relative contribution of each factor to modern climate change in class.